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ABSTRACT

Implications of research into human ability and metacognition for adaptive instruction are examined. Traditionally, adaptive instruction has largely involved the adaptation of instruction to suit the cognitive idiosyncrasies of individual learners. Through the development of learning strategies and metacognitive abilities to manage them, this paper discusses how adaptive instruction should aim at fully interactive adaptation between the learner and the instruction. Studies reviewed equate mental effort with depth of processing, and suggest that little will be learned, in terms of schema change, unless mental effort is invested by the learner. For adaptive instruction to be truly effective, learners must be challenged, but not to the point where they no longer believe they can succeed. Conclusions are drawn concerning the relative effectiveness of adapting instruction to learners and learners to instruction. Implications for the design of adaptive instruction are presented. (PN)

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Learning Strategies and Adaptive Instruction

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Introduction.

A great deal of attention is currently being paid to cognitive processes that become active when people learn something. In particular, scholars are beginning to describe human aptitude and ability in terms of skill in various cognitive processes rather than just in terms of performance on aptitude tests (Snow, 1980), and to study the degree to which learners can achieve awareness of and control over these processes (Brown, 1981; Brown, Campione & Day, 1981). In the first instance, studies of tests and test-taking have shown that the construct validity of aptitude tests is often suspect, and that what was thought to be measured was in fact not measured (see Hunt, 1976, 1978; Hunt, Frost & Lunneborg, 1973; Hunt, Lunneborg & Lewis 1975, who suggest that tests of verbal aptitude, e.g. the V2 synonyms test from the "French Kit" (French, Ekstrom and Price, 1963), in fact measure general speed of processing rather than skill with language; and Lohman (1977) who has provided evidence that success on the Paper Folding Test has to do with logical scanning rather than spatial ability.) In addition, non-empirical work, such as that conducted by Carroll (1976), has attempted to analyze and classify aptitude tests in terms of the processes they measure. Approaching the same question from a

different direction, scholars such as Das and his associates (Das, Kirby & Jarman, 1975, 1979) have developed a theory of human ability based upon cognitive processes.

In the second instance, it has become increasingly apparent that learners possess certain "metacognitive" skills or "cognitive strategies" (Gagne and Briggs, 1977) through which they can monitor and control their own learning. Whether this phenomenon is thought of in terms of awareness of one's own learning strategies, a process that has been studied by Peterson, Swing, Braverman and Buss (1982), in terms of a learner's cognitive "self-control" (Landa, 1974), or in terms of cognitive behavior that is purposeful and planned (Das, 1980; Das and Jarman, 1981), the common denominator is the belief that learners, particularly those of high ability (Bovy, 1981), are capable of deciding for themselves how they will tackle a particular task, or of being taught the skills that will enable them to do so.

The purpose of this paper is to look at some of the implications of this research into human ability and metacognition for adaptive instruction. The paper will take the position that, traditionally, adaptive instruction has largely involved the adaptation of instruction to suit the cognitive idiosyncrasies of individual learners. In other words, it has been designed in order to engage those cognitive processes which

mental ability has made learners particularly adept at using, or to compensate for those skills learners are weak in. On the other hand, research in metacognition has shown that learners are capable, to varying degrees, of taking charge of their own learning. The paper will look at how, through the development of learning strategies and metacognitive abilities to manage them, learners can be "adapted" to instruction, rather than the other way around. Adaptation will be considered to be the mutual and reciprocal adaptation of the learner to instruction, not just adapting instruction to suit the learner.

Learning, Ability and Instruction.

Before looking at how instruction can be adapted to learners, and learners to instruction, it is necessary to see how the cognitive processes we talked about above relate to mental ability, to learning strategy, and to instruction. Figure 1. illustrates these relationships.

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Figure 1 about here

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The diagram begins with the cognitive processes themselves. These are the psychological mechanisms by means of which we learn. It is intended that they include the kinds of processes

that Shuell (1980) identified as psychological processes (as opposed to instructional variables), or which Bransford (1979) called "learning activities" in his "Framework" for exploring learning. It is assumed that all learners, except for the mentally handicapped, have the potential for using any or all of these processes. However, the degree of aptitude in each process varies from learner to learner. All normal learners have the potential ability to form mental images (a basic cognitive process). However, only some learners are good at imagery. In such learners, we can say that the basic process has achieved the status of a "mental skill". It is, of course, at the level of mental skill, thus defined, that one common type of individual difference among learners emerges. A third degree of involvement of basic processes in learning is arrived at when learners bring their mental skills to bear on particular learning tasks. This does not always happen. Indeed, there is no guarantee whatsoever that learners who are good at a particular cognitive process will use it when it is appropriate to do so. This is borne out by studies in which simply telling subjects what skills to use improves performance, even when those subjects are skilled in the processes they need to employ (see, for example, studies by Thorndyke and Stasz, 1980, and Winn, 1982c).

What is important for this paper is this last point. In many instances, it is insufficient simply to adapt instruction to learners on the basis of individual differences in mental skill.

We have to go further than that, and take learning strategies, defined as appropriately applied mental skills, into account. In this regard, it is useful to think of instruction as the control of learning processes, as Shuell (1980), among others, has done. However, looking at figure 1., we realise that the psychological mechanisms, which are learning processes, cannot be controlled directly. To do so would probably require that "instruction" take the form of chemical or electrical stimulation of the central nervous system, which is both impractical and unethical. Instructional control over learning processes can therefore only be exercised indirectly, by getting learners to apply appropriate learning strategies. As the model suggests, this control can either come from within or from outside the learner. When it comes from within the learner, then metacognitive abilities are involved. When it comes from without, the learner is dealing with any of a number of possible types of instructional strategy.

Instructional control can intervene in a number of ways in the learning process. Instructional strategies can be used to help the learners develop the mental skills they will need in order to learn. Or they can be used to indicate to the learners, directly or indirectly, which learning strategies to use. Or else instructional strategies can help learners develop their own metacognitive skills. Each one of these types of intervention is important in adaptive instruction, as we shall see.

When instructional strategies are aimed at learning strategies, than a number of things can happen. One of the most useful distinctions to make is between "detached" and "embedded" instructional strategies (Rigney, 1978). A detached strategy is a set of directions to the learner about which strategy to use. When reading a poem, learners could simply be told to conjure up a mental image of the poem. Or, as in the Thorndyke and Stasz (1980) study mentioned above, learners studying maps could be told to mentally divide a map into quadrants, learn what was in each quadrant, and finally put the quadrants together. An embedded strategy, as its name implies, is less direct. The materials themselves model the strategy that is to be used. A good example of this is given by Salomon (1974), where zooming in and out in a film modelled the process of locating details in pictures relative to other details and the picture as a whole, and improved recall of the details in the picture. Other examples might include any materials which contain hints as to how they are to be processed, such as visual cueing (Dwyer, 1971, 1978), spatial structuring (Winn and Holliday, 1982), and so on.

The role of instructional strategies in the development of mental skills is less familiar to us. For a while now, research has been offering evidence that mental abilities <u>can</u> be developed, and are not as immutable as has traditionally been thought. The work of Feuerstein (1979) in developing mental skills in the learning disabled, and of Kaufman (1978) in

training the handicapped to use successive processing skills are testimony of this. What is more, it has been demonstrated that learners can be taught specific skills which they can then apply as strategies. Weinstein (1978) trained grade nine learners in imagery elaboration of verbal materials in seven sessions. Imagery elaboration proved a useful skill when applied to such tasks as telling veins from arteries, remembering items on a shopping list, and distinguishing road signs by their shapes. In another study, Weinstein, Underwood, Wicker and Cubberly (1979) trained subjects in the loci method for remembering lists of words. Winn (1982c) used computer modelling to train subjects in the skill of mental partitioning of visual displays in order to learn patterns of letters. Dansereau et. al. (1979) developed what amounted to a skills training curriculum for university students. And Wittrock (1982) describes research where strategies have been taught to learners enabling them to relate their own experiences to text they are to read and comprehend.

In all of these cases, the assumption was that subjects did not have the necessary mental skills in order to employ the appropriate strategy. In the case of embedded and detached strategies, the assumption was that the learners had the skills, but needed to be told when to use them. The last type of instructional intervention aims at developing metacognitive abilities so that learners can make strategic decisions for themselves. The development and deployment of metacognitive

skills appears to be related to ability. Basing her argument upon research by Salomon (1979), Bovy (1981) describes relationships between ability and the type of instructional support learners require. She offers a great deal of evidence in support of the suggestion that high ability learners are capable of deciding for themselves which strategy to use, while low ability learners need to be told which strategy to use, and to have it modelled for them. A similar line of argument has been presented by Snow (1979). He provides evidence that giving learners control over their own instruction is not by any means the best thing to do. This is because learners do not necessarily know what is best for them, and even when they do know, they may not act on that knowledge. Snow also reports that students scoring high on tests of fluid ability scored better than low ability students in an instructional program (BIP) requiring a high degree of learner control. This suggests that "high ability" might in fact mean high metacognitive ability. The inference that one can draw from Bovy's and Snow's research is that special skills are needed if learners are to be able to control their own instructional environment. These skills should not be taken for granted, and should be taught and nurtured.

We can now see that adaptive instruction can operate in two ways. Instruction can be designed to meet individual learner differences, which in effect means compensating for weak skills or activating strong ones (Salomon, 1979). And learners can be

"adapted" to suit instruction through training in mental skills, directions as to which learning strategy to use (either through being told or through modelling in the materials), and through training in metacognitive skills, which will allow them to select appropriate learning strategies for themselves.

Adaptive Instruction.

To date, however, adaptive instruction has paid less attention to the second form of adaptation. There are two ways in which instruction has been adapted to individual learner differences. These are referred to, by Snow (1980), as macro- and micro-adaptation. Macro-adaptation follows from the ATI tradition, and relies upon diagnosis of learner ability prior to instruction, and the prescription of instructional treatments accordingly. Micro-adaptation, on the other hand, allows for adaptation of an instructional system to the learner during instruction. The assumption is that, as the learner learns, the type of instructional support will change. For instance, the need for detached strategies may decline. This type of adaptation is best exemplified in relatively sophisticated computer-assisted instruction of the kind developed by Atkinson (1976) and Suppes (1977), and in Pask's (1975) "steady state technique", where instructional systems continuously adjust upper and lower difficulty limits so that the learner is always challenged but

never overwhelmed.

However sophisticated and complex these instructional systems might be, they still rely upon adaptation to rather than by the learner. The exception is what has traditionally been referred to as "remediation" (Salomon, 1972; Shuell, 1980). In this case, rather than instruction compensating for abilities in which the learner is weak, or activating those in which the learner is more competent, the learner is taught skills or knowledge that are prerequisite to the course or unit that has to be studied. The difference between this and the other approach to adaptive instruction can be illustrated from Glaser's (1977) five models of adaptive instruction.

We can justifiably exclude Glaser's first model from the discussion. This model describes a situation where, if the learner does not possess the prerequisite mental skills for a particular unit of instruction, then he is not even admitted to the unit. No attempt is made to "adapt" the instruction to the learner, or the learner to the instruction, beyond, perhaps, providing some alternative instructional methods from which the learner might choose. Glaser's third model is an example of traditional macro-adaptation. In this alternative, the learning environment is matched with a learner's initial competence. We can infer that this adaptation might capitalize on existing skills or compensate for absent ones. Glaser's second model is an

example of remediation. Prerequisite competencies are developed, but if learners still fail after attempting the material, they are not allowed to proceed further. The fourth model is a combination of these two. If none of the available instructional environments matches the initial competence, then the initial competence is developed to match one of them. Glaser's fifth model allows learners to achieve different goals based on their initial competence.

In Glaser's five models of adaptive instruction can be seen, therefore, suggestions arising out of the ATI tradition, and out of the need for remediation in the cases of some learners. We find the suggestion that instruction should be adapted to learners, and also that learners, by training in prerequisite skills, can, to some extent, be "adapted" to instruction. However, we do not find any directions concerning the development of metacognitive skills, nor for the development of mental skills that will apply beyond the "local" set of learning tasks. What is more, there is no mention of telling the learner which learning strategy to use. This limitation in the degree to which the learner is encouraged to adapt to instruction stems in all likelihood from the notion that teaching "initial competencies" is remedial. In such an approach, there is the suggestion that the learner is in trouble, and that to teach mental skills is something of a last resort. It is the contention of this paper that this is the wrong approach to take in adapting learners to

suit instruction. As stated at the beginning of the paper, adaptive instruction should aim at fully interactive adaptation between the learner and the instruction. Strategy training, development of metacognitive abilities, and telling the learner which strategy to use, should be considered equally with adapting instruction to suit learner needs, not as a last resort. The advantages of this approach to adaptive instruction go beyond capitalizing on the ability of the learner to learn and choose strategies. Instruction can be made more challenging for those learners who need challenge. The best strategies can be brought to bear on particular tasks, even if the learners do not initially have the mental skills to apply them. And, often, it will turn out to be more cost effective to teach learners strategies than to develop several versions of instruction to meet learner needs, or to develop complex instructional systems for micro-adaptation.

What Affects Learners' Perceptions of Instruction

The way learners adapt to instruction is determined largely by their perception of what the learning task is, and by their assessment of their own ability to complete it. These two factors have been called "Perceived demand characteristics" and "Perceived self efficacy" by Salomon (1981). Basic to both of these constructs is the idea that learners interpret information about a learning task in the same way that they interpret

information about anything else -- by attributing meaning to it on the basis of existing knowledge. What a learner knows will lead to the anticipation of events and information in the instructional environment, and will influence the way in which the instructional environment is searched (Neisser, 1976). The meaning that information conveys to the learner is therefore determined by what the learner attributes to it (see Bandura, 1978; Salomon, 1982), and not to any objective and intrinsic value that the information itself possesses.

These ideas are not particularly new when considering the information that a particular task requires the learner to process. However, when applied to information about the task itself, a number of issues arise that are relevant to adaptive instruction. What the learner knows about the task ahead of time has a great deal of influence upon the way the task will be performed. Bartram (1978) and Winn (1982c), both using pattern recognition tasks, showed that precueing learners as to which of two tasks to perform improved performance when compared to that of subjects who were not told until after presentation of the stimuli how to process them.

As far as perceived self efficacy is concerned, Salomon (1981) has suggested that the relationship between it and achievement can be described by an inverted U function. In other words, students who believe that they are incapable of learning a

particular task, or those who believe that to do so would be exceptionally easy, succeed less well than those who rate their chances of success somewhere between these two extremes.

However, the effect of perceived demand characteristics and perceived self efficacy upon performance is indirect. What the learner sees the task to be, and how the learner assesses his own chances of success determine the amount of mental effort that will be invested in the task, which in turn influences success, (Salomon, 1981, 1982, 1983). Salomon equates mental effort with depth of processing, and suggests that little will be learned, in terms of schema change, unless mental effort is invested by the learner. The absence of mental effort Salomon equates with "mindelessness", a term he takes from Langer (1982).

In a typical experiment (reported in Salomon, 1983), sixth grade children were asked to state their preconceptions of the "difficulty" of print and television. They were then shown a film or a text covering equivalent content, and were asked to estimate how much mental effort they had invested in learning the material. Reported mental effort correlated highly with achievement for both groups. What is perhaps more interesting is that there was a significant positive correlation between the investment of mental effort and reported self efficacy for the print group, and a significant negative correlation for the television group. By and large, the children felt that

television was "easy" and print was "hard". Also, children attributed success at learning from print to their "smartness" and success at learning from television to the fact that it was easier to learn from. All of this suggests that the more mental effort that is invested the more successful the student will be, and that when the task is seen to be challenging, the better a student feels he will do, the more effort he invests, while when the task is seen as easy, the better the student thinks he will do, the less effort he invests.

These conclusions receive support in an interesting paper by Clark (1982). Here, a number of ATI studies are reviewed in which it is apparent that students learn least from the methods they like most, and learn most from the methods they like the least. Clark attributes this negative relationship between learner preference and performance to the fact that learners like the "easiest" methods that require them to invest the least mental effort. And of course methods that elicit the least investment of effort lead to "mindless" and "shallow" processing and the least amount of schema change.

What this means for adaptive instruction is that when attempts are made to adapt learners to instruction, success will depend on certain perceptions and attitudes the learners have. The degree to which learners can be induced to employ appropriate learning strategies depends on how well they have understood the

task, and whether they consider it to be worth a lot of mental effort or only a little. Frequently, learners will prefer a strategy because it requires little mental effort. However, this preference will probably lead to their learning less. For adaptive instruction to be truly effective, learners must be challenged, but not to the point where they no longer believe they can succeed.

Conclusions

In light of all of this, several conclusions can be drawn about the relative effectiveness of adapting instruction to learners and learners to instruction. Also, there are implications for the design of adaptive instruction. These are now presented.

1. Attempts to adapt instruction to learners by compensating for mental skills that are weak or absent or by engaging only those mental skills that are known to be well developed is possibly counterproductive. The reason for this is that making the task easier will reduce the amount of mental effort the learner invests in it. This in turn will reduce the learner's success in completing the task. Of course, there is a question of degree that enters into this issue. There will be occasions when compensation is necessary, or when learners will need

instructional methods that draw upon their cognitive strengths. However, there will also be occasions when making the task easy for the learners will reduce the amount that is learned. Instruction should always be sufficiently challenging that the learner processes the information that is given "mindfully". This will not happen when the instruction itself does all of the mental work for the learner.

2. In order to get the learner to adapt to the instruction, care should always be taken that the learner knows which learning strategy is the most appropriate. Except in the case of learners who, by virtue of the fact that they possess high metacognitive abilities, are capable of deciding on the best strategy for themselves, all instruction should indicate which learning strategy should be brought to bear on the task at hand. In the case of low-ability learners, the materials should as far as possible model the cognitive processes that should be used. For other learners, it may be simply sufficient to tell them which strategy to use in sets of instructions given either before or during instruction.

3. However, for the learner to be able to adapt to instruction as a result of embedded or detached instructional strategies, the learner must have a sufficiently large repertoire of mental skills that can be used as learning strategies. Efforts should therefore be made to develop such a repertoire. This might be

done in one of two ways. Either learners could be taught mental skills apart from particular content. Or they might be taught mental skills in particular instructional tasks that would then transfer easily to other tasks. To do this, instruction would constantly have to remind learners of situations in which they had previously applied the same relevant strategy. It is quite likely that the transfer of learning strategies from one situation to another could be achieved through analogy, in ways that have been studied by Gick and Holyoak (1980).

4. It is to be hoped that eventually learners will be weaned away from instructional support that tells them each time they are faced with a task which strategy to use. This instructional support can end up making it easier for them, just as developing compensatory instruction does, with the result that less mental effort will be invested. In order to achieve this end, efforts must be made to develop metacognitive skills in learners. Perhaps practice in problem solving would be a useful method. It must be stressed, though, that metacognitive ability will not be much use to learners unless they have a large number of strategies to choose from. One cannot succeed without the other.

5. Learners must be encouraged to invest mental effort in the tasks they are to perform. There are two aspects to this. First, they must really understand what the task requires of them. Of course, we have always insisted that learners be told what the

objectives of a particular lesson are in order that they might adopt a relevant orientation to the task and anticipate such things as the organization of the content. However, that is not enough. In thoroughly understanding the demands that the task will place upon them, learners are well on the way to discovering which strategies they should use in order to complete it successfully. The interpretation of the task, and the assimilation of it to existing schemata in the same way that new knowledge is assimilated, implies that once the task has been thoroughly understood, a great deal of learning has already taken place. Knowledge of task is therefore not just something that has to occur before learning can take place. Its acquisition is an important part of learning itself.

The second thing that has to occur if learners are to invest mental effort in a learning task is their belief that they are capable of succeeding. The task must not appear unattainable; nor must it appear so easy that the learner will not feel the need to invest mental effort. The task must be presented in ways that the learner has the mental skills to deal with. Or else the mental skills to deal with it can be taught. This does not mean that learners will necessarily enjoy the method that they have selected or been told to use. However, they must believe that it is the best for them.

6. The instruction itself should continue to be adaptive once it

has begun. (This is "micro-adaptation"). It should also continue to be interactive adaptation in the sense that as the learner adapts to instruction, the instruction adapts to the learner. For instance, the need to specify learning strategies overtly will probably decrease as instruction progresses and as the learner selects more efficient ways of dealing with it. Instruction would therefore adapt as the learner adapts by reducing the number of detached strategies and the degree of modelling of cognitive processes. Thus, adaptive instruction would truly become a "Conversation" (Pask, 1975), where learner and instructor are in constant dialogue allowing continuous adaptation of learner to instruction and instruction to learner.

7. All of this has implications for the design of adaptive instruction. Relative emphasis shifts from concern with the characteristics of the learner to concern with the nature of the task, and the demands it makes on the learner's cognitive system. Rather than determining the nature of instruction on the basis of what is known about the learner, the option is now open to start with the task, to define the optimum learning strategy, and to tell the learner to use that strategy, or teach it should it not be available to the learner. There are occasions where such an approach would be more cost effective than designing and creating adaptive instructional materials. The trade-off is between creating instruction that contains a great deal of redundancy because it includes different ways of teaching the same thing in

anticipation of great differences in the learners' abilities; or providing just one "version" of instruction, and training the learners to use it.

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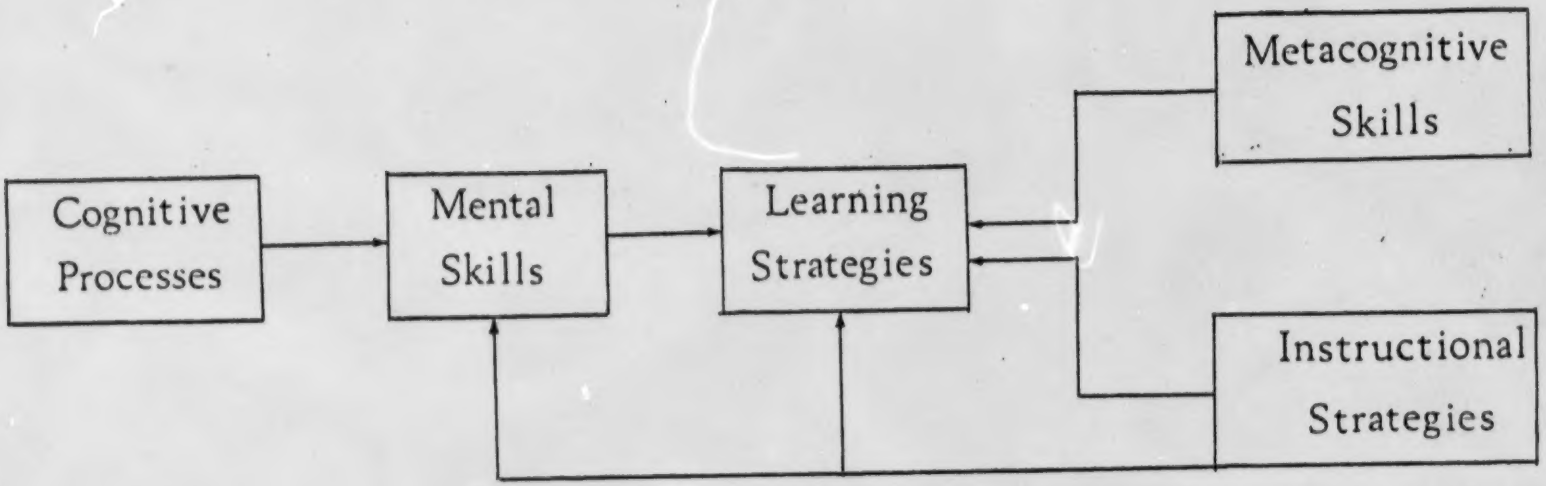
Cognitive Processes
Mental Skills
Learning Strategies
Metacognitive Skills
Instructional Strategies